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ENVIRONMENTAL AND PRODUCTION EFFECTS OF AMINO ACID NUTRITION IN LAYING HENS

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Environmental and Production Effects of Amino Acid Nutrition in Laying Hens Final Report # 20030432

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Abstract

The objective of this research was to examine the effects of dietary levels of amino acids on hen productivity and manure nutrient content. Treatments 1 through 3 were formulated to provide hens with a minimum of 660, 720 and 780 mg of lysine per day, respectively through out the experiment, with diets adjusted in response to changes in feed intake. Treatments 4, 5 and 6 provided different levels of lysine intake in a phase feeding approach with lysine intake adjusted in 12 week phases. Treatments 4, 5 and 6 provided lysine intakes of 780/720/660/600, 720/720/660/600 and 780, 780, 720 and 660 mg, respectively in the four 12 week periods in the experiment. Hens in treatments 7, 8 and 9 were fed diets containing 0.66, 0.72 and 0.78% lysine (equivalent to 660, 720 and 780 mg of lysine at 100 grams feed intake per day per hen), and diet levels were not corrected for changes in daily feed intake. Essential amino acids were kept at a minimum ratio to dietary lysine content in all diets. Two White Leghorn strains were used. Each treatment was replicated four times (15 hens per replication) per strain of birds. Hens were on trial from 18 to 65 wks of age and manure was collected from sample hens at 29, 41, 53 and 65 wks of age. Data were analysed as a 9 x 2 factorial analysis with treatment and strain as the main effects. There were no diet by strain interactions so the data are reported only as main effects. Dietary treatments had no effect on egg production, feed intake, mortality and egg shell quality. Similarly, the volume of manure excreted and Ammonium-N, calcium, K2O, magnesium, P2O5, phosphorus, potassium, and sodium content of the manure were unaffected by diet. Body weight, feed efficiency (lower feed to egg mass ratio) and egg weight increased as amino acid intake increased, while nitrogen retention decreased. Total nitrogen and sulfur excretion increased with increased amino acids in the diet. Based on egg size and feed efficiency, White Leghorn hens required a minimum of 720mg of lysine per day.

Introduction

The protein and amino acid requirements recommended for laying hens by NRC (1994) are based on experiments using hens with much lower egg production and higher feed intake than the hens used today. Therefore, little information is available on the amino acid requirements of the modern high producing laying hen. The ideal protein concept in poultry is based on the balance of amino acids which precisely meets the bird's needs at a certain age and level of production, without deficiency or excess. This concept allows for more efficient use of protein in the diet and permits a certain reduction in dietary crude protein (Kerr and Kidd, 1999), which is friendlier to the environment because of reduced nitrogen excretion (Emmert and Baker, 1997). Ideal protein concepts are receiving considerable attention in other types of poultry, particularly broilers, but research in laying hens is lagging behind. In this concept, one amino acid is chosen as a reference amino acid, usually lysine in poultry, and the requirements of the other essential amino acids are predicted based on their ratio to lysine. In broilers, requirements of the birds change with age, however, the relative ratio of each amino acid to lysine remains the same as described by Cooley and Classen (2002). The objective of the present study was to determine the lysine requirement in laying hens using the ideal protein concept and based on performance criteria. An additional objective was to study the impact of ideal protein intake on the nutrient content of manure.

Methods

A total of 1080 White Leghorn hens of two different strains (Babcock and Shaver White) were used in this experiment. Birds were purchased from commercial hatcheries and raised in floor pens based on recommendations from primary breeders. At 17 weeks of age, birds were randomly placed in cages in an environmentally controlled room, and light stimulated at 18 weeks of age. Each replication had 15 birds in five cages, with each cage housing three birds at 464 cm^2 per hen. A total of four replications per dietary treatment per strain for a total of eight replications per dietary treatment were used in this study.

A combination of nine dietary treatments were used in this experiment (Table 1) to provide different levels of daily lysine intake per day. Diets were formulated to provide one of four levels of daily lysine intake, 600 mg, 660 mg, 720 mg and 780 mg based on hen feed intake (Tables 2, 3, 4, and 5). Treatments 1 to 3 were formulated to provide 660, 720 and 780 mg of lysine per hen per day, respectively. Treatments 4 to 6 were phase programs where the daily intake of lysine was adjusted every four weeks as shown in Table 1. In order to maintain the same (or similar) levels of lysine intake, diet formulations were adjusted to match hen feed intake for treatments 1 to 6. Treatments 7 to 9 were not corrected for feed intake and were formulated based on 100 grams of daily intake per hen. Feed intake was measured on a weekly basis from 18 to 29 weeks of age and then on a biweekly basis for the rest of the experiment. Diets were changed to the next intake level when bird intake reached that

intake plus 2 grams. All the diets were isocaloric (2850 kcal/kg) for the entire experiment. Lysine and other amino acids daily intakes were formulated to minimum amino acid ratios according to NRC (1983 and 1994) and Jais et al. (1995) (Table 6). Body weight was measured on a biweekly basis using sample birds, 12 birds per treatment, and all birds were weighed at 18 and 65 weeks of age.

Egg production, on a replication basis, was recorded on five days per week and corrected to a seven day per week basis. Egg weight was calculated on a weekly basis using all the eggs from each replication. Specific gravity was measured using all the eggs on one day from each replication every four weeks starting at 21 weeks of age and albumen quality was measured at 39 and 63 weeks of age using five eggs from each replication. Feather covering was assessed on all birds at 59 weeks of age according to Davami et al. (1987). A total of 15 birds per treatment per strain were killed by cervical dislocation at 65 weeks of age, for breast muscle and fat pad weights measurement.

Faecal collections were done on selected birds moved into individual cages one week in advance of collection at 29, 41, 53 and 65 weeks of age. Each treatment by strain subclass was replicated twice for a total of 4 birds per treatment. Manure was collected daily for 2 days in trays lined with plastic sheets, placed under the cages. At collection, efforts were made to remove feathers and feed particles from the trays. After collection, samples were mixed, freeze dried and a portion was analyzed for moisture (AOAC, 1990) and uric acid (Marquardt, 1983). Another portion was sent to Northwest Lab[1] for nutrient content analysis (ammonium-N, calcium, K2O, magnesium, P2O5, phosphorus, potassium, sodium, organic nitrogen, total. nitrogen, and total sulphur). Nitrogen utilisation was calculated using the nitrogen daily intake and the nitrogen content in the manure.

Statistical Analyses

Data was analyzed by ANOVA using the General Lineal Models procedure of SAS Institute Inc. (1999) with the main effects of dietary treatments and strain. Results were considered significant at $P < 0.05$. Apriori contrasts were used to determine differences when the ANOVA proved significant.

Animal Care

Experimental techniques used in these experiments were conducted in accordance with guidelines set out by the Canadian Council on Animal Care (1993). All animal protocols were approved by the Animal Care Committee at the University of Saskatchewan.

Results

Egg production

Dietary treatment had no effect on overall egg production when measured by total hen day production (THDP) (Table 7). In this experiment, increased amino acid intake did not affect overall egg

[1] Norwest lab, 7217 Roper Street. Edmonton, AB, Canada, T6B 3J4

production. These results are in concordance with data reported by Novak et al. (1999). A strain effect was however observed as Shaver birds produced more eggs than the Babcock birds. In this experiment, the range of amino acids used in dietary treatments was relatively small, and all the diets were balanced for essential amino acids. This could explain the absence of difference between treatments for egg production. This would suppose that as long as the amino acids are balanced, diets providing 660 mg of lysine per day could support egg production in White Leghorn hens. However, diets with low levels of lysine (660 mg and 600 mg per day) may not provide sufficient safety margin to guard against ingredient variability. Interestingly, all phase treatments and treatment 1 (660 mg lysine) had numerically lower egg production.

Feed intake

Overall feed intake (grams per hen per day) was not affected by dietary treatment (Table 7), and the two breeds consumed the same amount of feed during the experiment. This could be explained by the fact that all diets were formulated to be isocaloric and that hens consume feed based on the energy level of the diet as described by Stevens (1993). Sohail et al. (2002) reported an increase in feed intake with increased amino acid levels in diets, which is in disaccord with the results from this experiment. This may be explained by the fact that all the dietary treatments in this experiment were formulated to maintain a balance between the amino acids.

Actual lysine intake was higher than indicated by the dietary treatment in this experiment (Table 9). This is explained by the fact that diets were formulated based on daily feed intakes of 80, 90, 100, 110 and 120 grams per day but diets were only changed when feed intake increased 2 grams beyond the next feed intake level. Therefore birds consumed more lysine than indicated by the treatment descriptions. This experimental design was based on maintaining a minimum level of feed intake in each treatment and the logistics of measuring feed intake and changing diets. Feed ingredient variation could also have contributed to the higher lysine intake during the experiment.

Body weight

Body weight was affected by dietary treatment as shown in Table 7. At 65 weeks of age, diets 4 and 5, (both providing 600 mg of lysine during the last phase), resulted in significant lower body weight than all the other diets, with the exception for diet 1 (providing 660 mg of lysine corrected for feed intake).

Apriori contrasts indicated that at 65 weeks of age, phased diets had lower body weight than non-phased diets (Table 8). This confirms the work of Coon (2002) that phase feeding programs are more effective than non-phased program in controlling body weight. Also, contrasts showed that diet 7 (660 mg of lysine not corrected for feed intake) produced a heavier average body weight than diet 1 (660 mg of lysine corrected for feed intake) (Table 8). This can be explained by the lower lysine intake in the latter treatment. Data on fat deposition and breast muscle mass, even though not significantly

different, indicate that birds receiving 660 or 600 mg lysine corrected for feed intake had numerically the smallest fat pads and the smallest breast muscle mass. These data indicate that 600 mg of lysine per day is below the requirements of the modern White Leghorn hens and can not support tissue development and maintenance and that 660 mg of lysine per day is a marginal level that provides no safety margin for egg producers.

In regards to a breed effect, Shaver birds were heavier than the Babcock birds at the end of the experiments (65 weeks of age) (Table 7).

Egg weight

Overall egg weight was affected by dietary treatment (Table 7). Diets 3 produced larger eggs than diets 1, 4, 5, 6, and 7. This indicates that when compared to a diet providing 780 mg of lysine corrected for feed intake, phased diets reduce the overall egg size. Diets 1, 2, 4, 5, 6, 8, and 9 had the same overall egg weight. Diet 7 (660 mg not corrected for feed intake) produced the same size eggs than diets 1 (660 mg of lysine corrected for feed intake) and the phased diets (4, 5, and 6). Data from this experiment indicates the importance of nutrient delivery and its impact on the overall egg size. Birds fed diet 7 (660 mg of lysine not corrected for feed intake) had smaller eggs than birds fed diets 2, 3, 8, and 9 due to the lower levels of amino acid intake at the beginning of lay. Birds on diet 7 were receiving less than 660 mg of lysine when their feed intake was less than 100 grams per day.

Diet 3 produced larger eggs than the phased diets, which indicates the impact of amino acid levels during the production cycle on overall egg size. Increasing amino acids in the diet, numerically increased egg size, which is similar to the results of Keshavarz and Jackson (1992) and Novak et al, (1999).

Babcock birds produced larger eggs than Shaver birds.

Total Feed Egg Mass (TFEM)

Feed efficiency (TFEM) was affected by dietary treatment (Table 7). Diet 1 (660 mg of lysine corrected for feed intake) was less efficient in producing egg mass than diets 3 (780 mg of lysine corrected for feed intake), 8 (720 mg of lysine not corrected for feed intake) and 9 (780 mg of lysine not corrected for feed intake). Diets 1, 2, 4, 5, 6, and 7 were not significantly different for TFEM. This suggests that as amino acid levels increase in the feed, feed efficiency (TFEM) improves, which is in accordance with the work of Keshavarz and Jackson (1992).

Apriori contrasts showed that diet 3 (780 mg of lysine corrected for feed intake) was more efficient than diets 4 and 6 (phased programs using 780 mg of lysine in one or more phases) (Table 8).

No significant differences were observed between the two breeds for TFEM.

Total Feed Dozen Eggs (TFDE)

TFDE was not affected by dietary treatment as described in Table 7, however, Babcock birds were less efficient than Shaver birds when measured as the amount of feed required to produce a dozen eggs. This follows the results on feed intake and egg production mentioned above.

Specific Gravity and Haugh Unit:

The effect of dietary treatment and strain on specific gravity and haugh unit score are shown in Table 7. Specific gravity was not affected by dietary treatment or breed. This indicates that minerals have a greater effect on shell quality than amino acids. All the diets were formulated according to the mineral requirements of the laying hen. Haugh unit and albumen height were not affected by dietary treatment or breed at 39 and 63 weeks of age. In this experiment, the Haugh unit and albumen height declined as the flock aged which is in accordance with the findings of Silversides and Scott (2001).

Feather cover

Feather coverage was affected by dietary treatment (Table 7). Birds feed diet 1 (660 mg of lysine corrected for feed intake) had numerically the poorest feather coverage, birds receiving 720 mg or 780 mg of lysine had numerically better feather coverage. This would indicate that a lysine level of 720 mg of daily intake is a minimum to maintain feather coverage in White Leghorn. In this experiment, the two breeds had the same feather coverage at 59 weeks of age. Leeson and Walsh (2004) indicated that feathers have large content of protein and amino acids, deficiency in amino acids in the feed, especially sulphur amino acids, caused poor feathering. It is possible that in this experiment, treatment 1 was near deficiency in amino acids and feather growth was suffering in detriment of body maintenance and egg production.

Manure composition

Total nitrogen. Overall total nitrogen excretion was affected by dietary treatment (Table 10). Diet 6 (phased program with 780 mg of lysine during the first two phases) excreted more total nitrogen than diets 1, 4, 5, 7, and 8, but was not significantly different than diets 2, 3, and 9. Diet 2 excreted 7.6% more nitrogen than diet 1, and diet 6 excreted 12.9% more nitrogen than diet 4. Apriori contrasts (Table 11), showed that diet 3 (780 mg of lysine corrected for feed intake) excreted more total nitrogen than diet 4 (phased) but excreted less total nitrogen than diet 6 (phased program with 780 mg of lysine during the first two phases) during the experiment. Diet 2 (720 mg of lysine corrected for feed intake) excreted more total nitrogen than diet 8 (720 mg of lysine not corrected for feed intake). Increasing amino acids in laying hens diets resulted in increased nitrogen excretion. This is in accordance with the work of Summers (1993). Breed had no effect on overall total nitrogen excretion for the duration of the experiment.

Organic nitrogen. Overall, organic nitrogen production was affected by dietary treatment as shown in Table 10. Diet 6 (program with 780 mg of lysine during the first two phases) produced more

organic nitrogen than diets 1, 4, 5, 7, and 8, but was not significantly different than diets 2, 3 and 9. Diets 1, 2, 3, 4, 5, 7, 8, and 9 produced the same amount of organic nitrogen during the experiment. Breed had no effect on overall organic nitrogen excretion.

Ammonium nitrogen. Ammonium nitrogen was not affected by dietary treatments or breed during the experiment.

Uric acid. Results for uric acid (Table 10) showed that diets 2 and 6 excreted more uric acid than diets 1, 4, 5 and 7, while diets 3, 8 and 9 excreted the same amount of uric acid than diets 2 and 6. Even though not significantly, the results for uric acid followed the results for total nitrogen, which indicated that an increase in amino acids in the diet increased uric acid excretion. The ratio uric acid / total nitrogen was constant during the experiment (Table 10).

Nitrogen utilisation. Even though not significant, in this experiment, as amino acid levels increased in the diet, nitrogen utilisation decreased (Table 10).

Total sulphur. Minor differences were observed for total sulphur excretion (Table 10). This could be explained by the variation of sulphur content between the diets. Sulphur content in the diets increased with amino acid levels.

Other minerals. Overall Calcium, K_2O, magnesium, P_2O_5, phosphorus, potassium, and sodium were not affected by dietary treatment or breed (table 10). This could be explained by the absence of difference in feed intake between treatments, and feed was formulated based on feed intake and mineral contents were adjusted in consequence.

Volume of manure. The volume of manure excreted was not affected by the dietary treatment (Table 10). The two breeds excreted the same volume of manure during the experiment.

Conclusions

In this experiment, amino acid levels had an effect on body weight, egg weight, and feed efficiency (TFEM). Higher dietary amino acid levels resulted in increased body weight, larger eggs and improved feed efficiency. Egg production (THDP), feed intake, total feed per dozen eggs, and egg quality were not affected by amino acid levels. This would indicate that even low levels of well balanced amino acids (660 mg of daily lysine intake) could support egg production and egg quality. However, low levels of amino acids produced smaller eggs, which affect producers' income, and do not offer a safety margin against feed ingredient variability. Not providing enough amino acids to match the minimum requirements of the modern laying hens could have serious negative effects on the economics of an egg operation.

Manure composition was affected by amino acid levels in the diets. Organic nitrogen, total nitrogen, and total sulphur, increased as amino acids increased in the diet, however, the volume of manure excreted was not significant between the treatments. Other elements of the manure as

calcium, phosphorus, sodium, magnesium and potassium were not affected by the amino acid levels in the feed.

It would be possible to reduce nitrogen excretion by reducing amino acid and protein levels in layer diets, however, economics of egg production are not so straight forward. Reducing protein and amino acids levels may not affect egg production, but this reduction in amino acids will reduce egg size and therefore decrease economic returns of the egg production. Leeson and Summers (2001) reported and decrease of 2.3 grams per egg when the protein of the diet was reduced from 17% to 13%.

Recommendations

Based on this research, in order to improve and maintain egg size and efficiency without affecting egg production and feed intake, laying hen diets should provide a minimum of 720 mg of lysine per day. Phase feeding programs could be used to decrease feed cost, however, this may reduce late cycle egg size. Based on this experiment, providing a minimum of 780 mg of lysine at the beginning of lay would increase egg size and maintain it later on during the production cycle. As production declines with age, lysine level could be decreased to a minimum 720 mg per day. In order to maintain feather coverage a minimum of 720 mg of lysine is recommended in the diet. Loss of feather coverage could have significant effect on feed intake in a cold environment and decreased the performance of an egg operation. It is the responsibility of the egg manager to decide which feeding program to choose, ether a single diet for the entire egg production cycle (minimum of 720 mg of lysine per day) or a phased program starting with a minimum of 780 mg of lysine per day than reduced to 720 mg of lysine per day. Egg managers have to determine their feed cost and their returns per dozen eggs before choosing a feeding program. Data from lysine intake in this experiment showed the importance of measuring feed intake and make appropriate feed formulation corrections in order to match the daily requirements of the hen.

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Appendices

Table 1: Periods and dietary lysine levels provided per hen per day.

Treatment	Period	Lysine level
1	19 to 65 weeks of age	660 mg of lysine per day per hen corrected for feed intake
2	19 to 65 weeks of age	720 mg of lysine per day per hen corrected for feed intake
3	19 to 65 weeks of age	780 mg of lysine per day per hen corrected for feed intake
4	4 phases of 12 weeks	780 mg, 720 mg, 660 mg, 600 mg per day per hen
5	4 phases of 12 weeks	720 mg, 720 mg, 660 mg, 600 mg per day per hen
6	4 phases of 12 weeks	780 mg, 780 mg, 720 mg, 660 mg per day per hen
7	19 to 65 weeks of age	660 mg of lysine per day per hen based on 100 gram intake
8	19 to 65 weeks of age	720 mg of lysine per day per hen based on 100 gram intake
9	19 to 65 weeks of age	780 mg of lysine per day per hen based on 100 gram intake

Table 2. Ingredients and nutrients contained in diets providing 600 mg of lysine per day.

Daily intake (g/h/d)	90	100	110	120
ingredients				
Wheat	78.22	82.93	85.62	87.91
SBM[1] 48% CP	6.86	4.14	2.94	1.00
Canola oil	2.22	1.36	0.79	0.54
Dical. Phos[2].	1.13	1.04	0.94	0.81
Limestone	10.45	9.45	8.70	8.77
Layer mix [3]	0.50	0.50	0.50	0.50
Enzyme[4]	0.05	0.05	0.05	0.05
Sodium chloride	0.26	0.25	0.25	0.22
Choline chl.	0.10	0.10	0.10	0.10
Lys HCL	0.14	0.13	0.09	0.09
DL Met	0.07	0.05	0.02	0.01
L Thr	0.00	0.00	0.00	0.00
Calculated analyses				
AME (kcal/kg)	2850	2850	2850	2850
Protein %	17.26	16.77	16.63	16.10
Arg %	0.867	0.810	0.787	0.737
Lys %	0.667	0.600	0.545	0.500
Met %	0.287	0.258	0.235	0.215
TSAA %	0.624	0.592	0.569	0.542
Thr %	0.520	0.491	0.481	0.455
Iso %	1.142	1.095	1.081	1.035
Val %	0.662	0.656	0.628	0.602
Calcium %	4.20	3.80	3.50	3.50
Av. Phos %	0.42	0.40	0.38	0.35
Total Phos %	0.57	0.55	0.53	0.50

[1] Soybean meal.

[2] Dicalcium Phosphate: 15 % Ca, 21 % P.

[3] Supplied per kilogram of diet: vitamin A (retinyl acetate + retinyl palmitate), 8000 IU; vitamin D_3, 3000 IU; thiamine, 1.5 mg; vitamin B_{12}, 0.012 mg; pantothenic acid, 8 mg; vitamin E (dl-α-tocopheryl acetate), 250 IU; folic acid, 0.5 mg; biotin, 0.06 mg; niacin, 30 mg; riboflavin, 5.0 mg; menadione, 1.5 mg; iodine, 0.8 mg; copper, 10 mg; iron, 80 mg; zinc, 80 mg; manganese, 80 mg; selenium, 0.3 mg; ethoxyquin, 0.625 mg; zinc, 80 mg; and pyridoxine, 1.5 mg.

[4] Avizyme 1200, Finnfeeds International Limited, Marlborough, Wiltshire, UK, SN8 1XN

Table 3. Ingredients and nutrients contained in diets providing 660 mg of lysine per day.

Daily intake (g/h/d)	80	90	100	110	120
ingredients	% of diet				
Wheat	66.88	72.29	77.71	83.12	88.53
SBM[1] 48% CP	13.66	10.51	7.37	4.22	1.07
Canola oil	4.22	3.23	2.25	1.26	0.27
Dical. Phos[2].	1.50	1.32	1.13	0.95	0.76
Limestone	12.38	11.38	10.38	9.37	8.37
Layer mix [3]	0.50	0.50	0.50	0.50	0.50
Enzyme[4]	0.05	0.05	0.05	0.05	0.05
Sodium chloride	0.40	0.34	0.29	0.23	0.17
Choline chl.	0.10	0.10	0.10	0.10	0.10
Lys HCL	0.15	0.15	0.15	0.15	0.15
DL Met	0.13	0.11	0.08	0.06	0.03
L Thr	0.03	0.02	0.02	0.01	0
Calculated analyses					
AME (kcal/kg)	2850	2850	2850	2850	2850
Protein %	18.56	18.00	17.44	16.87	16.31
Arg %	1.018	0.950	0.881	0.813	0.744
Lys %	0.825	0.756	0.688	0.619	0.550
Met %	0.355	0.326	0.296	0.267	0.237
TSAA %	0.704	0.670	0.636	0.602	0.568
Thr %	0.627	0.585	0.544	0.502	0.460
Iso %	1.266	1.211	1.156	1.100	1.045
Val %	0.731	0.700	0.670	0.639	0.608
Calcium %	5.00	4.59	4.17	3.76	3.34
Av. Phos %	0.50	0.46	0.42	0.38	0.34
Total Phos %	0.65	0.61	0.57	0.53	0.49

[1] Soybean meal.

[2] Dicalcium Phosphate: 15 % Ca, 21 % P.

[3] Supplied per kilogram of diet: vitamin A (retinyl acetate + retinyl palmitate), 8000 IU; vitamin D_3, 3000 IU; thiamine, 1.5 mg; vitamin B_{12}, 0.012 mg; pantothenic acid, 8 mg; vitamin E (dl-α-tocopheryl acetate), 250 IU; folic acid, 0.5 mg; biotin, 0.06 mg; niacin, 30 mg; riboflavin, 5.0 mg; menadione, 1.5 mg; iodine, 0.8 mg; copper, 10 mg; iron, 80 mg; zinc, 80 mg; manganese, 80 mg; selenium, 0.3 mg; ethoxyquin, 0.625 mg; zinc, 80 mg; and pyridoxine, 1.5 mg.

[4] Avizyme 1200, Finnfeeds International Limited, Marlborough, Wiltshire, UK, SN8 1XN

Table 4. Ingredients and nutrients contained in diets providing 720 mg of lysine per day.

Daily intake (g/h/d)	80	90	100	110	120
ingredients					
Wheat	63.49	69.20	74.90	80.61	86.31
SBM[1] 48% CP	16.77	13.35	9.94	6.52	3.10
Canola oil	4.54	3.53	2.51	1.50	0.48
Dical. Phos[2].	1.48	1.30	1.11	0.93	0.74
Limestone	12.37	11.37	10.37	9.36	8.36
Layer mix [3]	0.50	0.50	0.50	0.50	0.50
Enzyme[4]	0.05	0.05	0.05	0.05	0.05
Sodium chloride	0.40	0.34	0.29	0.23	0.17
Choline chl.	0.10	0.10	0.10	0.10	0.10
Lys HCL	0.15	0.15	0.15	0.15	0.15
DL Met	0.10	0.09	0.07	0.06	0.04
L Thr	0.05	0.04	0.03	0.01	0.00
Calculated analyses					
AME (kcal/kg)	2850	2850	2850	2850	2850
Protein %	19.46	18.82	18.18	17.53	16.89
Arg %	1.101	1.026	0.950	0.875	0.799
Lys %	0.900	0.825	0.750	0.675	0.600
Met %	0.395	0.361	0.327	0.292	0.258
TSAA %	0.756	0.716	0.676	0.636	0.596
Thr %	0.684	0.635	0.586	0.537	0.488
Iso %	1.343	1.281	1.219	1.157	1.095
Val %	0.774	0.740	0.705	0.671	0.636
Calcium %	5.00	4.59	4.17	3.76	3.34
Av. Phos %	0.50	0.46	0.42	0.38	0.34
Total Phos %	0.65	0.61	0.57	0.53	0.49

[1] Soybean meal.

[2] Dicalcium Phosphate: 15 % Ca, 21 % P.

[3] Supplied per kilogram of diet: vitamin A (retinyl acetate + retinyl palmitate), 8000 IU; vitamin D_3, 3000 IU; thiamine, 1.5 mg; vitamin B_{12}, 0.012 mg; pantothenic acid, 8 mg; vitamin E (dl-α-tocopheryl acetate), 250 IU; folic acid, 0.5 mg; biotin, 0.06 mg; niacin, 30 mg; riboflavin, 5.0 mg; menadione, 1.5 mg; iodine, 0.8 mg; copper, 10 mg; iron, 80 mg; zinc, 80 mg; manganese, 80 mg; selenium, 0.3 mg; ethoxyquin, 0.625 mg; zinc, 80 mg; and pyridoxine, 1.5 mg.

[4] Avizyme 1200, Finnfeeds International Limited, Marlborough, Wiltshire, UK, SN8 1XN

Table 5. Ingredients and nutrients contained in diets providing 780 mg of lysine per day.

Daily intake (g/h/d)	80	90	100	110	120
ingredients					
Wheat	58.35	64.78	71.22	77.65	84.08
SBM[1] 48% CP	21.43	17.35	13.28	9.20	5.12
Canola oil	5.02	3.94	2.86	1.77	0.69
Dical. Phos[2].	1.45	1.27	1.09	0.91	0.73
Limestone	12.35	11.35	10.35	9.35	8.35
Layer mix [3]	0.50	0.50	0.50	0.50	0.50
Enzyme[4]	0.05	0.05	0.05	0.05	0.05
Sodium chloride	0.41	0.35	0.29	0.23	0.17
Choline chl.	0.10	0.10	0.10	0.10	0.10
Lys HCL	0.10	0.11	0.13	0.14	0.15
DL Met	0.20	0.17	0.13	0.10	0.06
L Thr	0.04	0.03	0.02	0.01	0
Calculated analyses					
AME (kcal/kg)	2850	2850	2850	2850	2850
Protein %	20.75	19.93	19.11	18.29	17.47
Arg %	1.226	1.133	1.039	0.946	0.853
Lys %	0.975	0.894	0.813	0.731	0.650
Met %	0.441	0.401	0.361	0.320	0.280
TSAA %	0.819	0.771	0.723	0.674	0.626
Thr %	0.741	0.685	0.628	0.572	0.515
Iso %	1.458	1.380	1.301	1.223	1.144
Val %	0.839	0.795	0.752	0.708	0.664
Calcium %	5.00	4.59	4.17	3.76	3.34
Av. Phos %	0.50	0.46	0.42	0.38	0.34
Total Phos %	0.65	0.61	0.58	0.54	0.50

[1] Soybean meal.

[2] Dicalcium Phosphate: 15 % Ca, 21 % P.

[3] Supplied per kilogram of diet: vitamin A (retinyl acetate + retinyl palmitate), 8000 IU; vitamin D_3, 3000 IU; thiamine, 1.5 mg; vitamin B_{12}, 0.012 mg; pantothenic acid, 8 mg; vitamin E (dl-α-tocopheryl acetate), 250 IU; folic acid, 0.5 mg; biotin, 0.06 mg; niacin, 30 mg; riboflavin, 5.0 mg; menadione, 1.5 mg; iodine, 0.8 mg; copper, 10 mg; iron, 80 mg; zinc, 80 mg; manganese, 80 mg; selenium, 0.3 mg; ethoxyquin, 0.625 mg; zinc, 80 mg; and pyridoxine, 1.5 mg.

[4] Avizyme 1200, Finnfeeds International Limited, Marlborough, Wiltshire, UK, SN8 1XN

Table 6: Amino acid ratio based on lysine.

Amino acid	Percent of Lysine
Lysine	100
Arginine	101
Methionine	43
Methionine + Cystine	84
Threonine	76
Isoleucine	79
Tryptophan	23
Valine	86

Table 7: Overall bird performance from 19 to 65 weeks of age

	Treatments									Strain		SEM	X
	1	2	3	4	5	6	7	8	9	Babcock	Shaver		
THDP[1] (%)	86.36	88.15	87.55	86.72	86.21	86.12	88.43	88.44	88.48	85.99^{B}	88.78^{A}	0.374	NS
Feed intake, (g/hen/d)	105.67	105.88	106.02	104.78	104.60	105.25	106.37	105.85	104.93	105.87	105.10	0.281	NS
Body Weight (g)	1.73^{bc}	1.81^{a}	1.83^{a}	1.69^{c}	1.72^{c}	1.79^{ab}	1.81^{a}	1.81^{a}	1.85^{a}	1.73^{B}	1.84^{A}	0.011	NS
TFEM[2]	2.14^{a}	2.08^{abc}	2.07^{bc}	2.11^{abc}	2.14^{ab}	2.13^{ab}	2.12^{ab}	2.07^{bc}	2.04^{c}	2.10	2.10	0.008	NS
TFDE[3]	1.47	1.44	1.45	1.45	1.46	1.47	1.44	1.44	1.42	1.48^{A}	1.42^{B}	0.007	0.0668
Egg Weight (g)	57.1^{bcd}	57.7^{abc}	58.5^{a}	57.3^{Bcd}	57.0^{cd}	57.5^{bcd}	56.7^{d}	58.0^{abc}	58.0^{ab}	58.7^{A}	56.4^{B}	0.180	NS
Specific gravity	1.0845	1.0836	1.0840	1.0847	1.0835	1.0842	1.0835	1.0836	1.0841	1.0840	1.0839	0.00012	0.0447
Haugh Unit at 39 weeks of age	101.20	100.69	100.00	100.10	100.29	98.53	99.78	99.36	99.91	101.02^{A}	98.95^{B}	0.388	NS
Haugh Unit at 63 weeks of age	95.23	91.35	92.65	94.13	90.67	92.49	93.92	94.26	91.68	95.19^{A}	90.80^{B}	0.500	NS
Feather coverage at 59 weeks*	13.09^{c}	14.97^{ab}	14.66^{abc}	13.57^{bc}	14.25^{abc}	15.37^{a}	14.93^{ab}	14.47^{abc}	15.55^{a}	14.46	14.62	NS	0.181
Breast yield (% body weight)	10.96	10.77	11.09	10.96	10.99	10.68	11.05	11.00	11.09	10.67^{B}	11.24^{A}	0.0642	0.3959
Fat pad (% body weight)	3.56^{bc}	4.14^{abc}	4.23^{abc}	3.46^{c}	3.89^{abc}	4.44^{a}	4.37^{ab}	4.34^{ab}	4.72^{a}	3.79^{B}	4.47^{A}	0.0945	0.2327

[1] Total Hen Day Production, [2] Total Feed Egg Mass, [3] Total Feed Dozen Egg

*feather coverage: maximum score 20

[a-b-c-d] Means within a row with no common superscript differ significantly ($P<0.05$)

Table 8: Apriori contrasts P values for bird performance from 19 to 65 weeks of age.

	Contrasts						
	1 vs 7	2 vs 8	3 vs 9	3 vs 4 & 6	2 vs 5	3 vs 4	3 vs 6
THDP [1] (%)	0.1374	0.8342	0.5029	0.3472	0.1634	0.5497	0.3027
Feed Intake (g/hen/d)	0.5924	0.9806	0.4248	0.3948	0.3486	0.3631	0.5721
Body weight (g)	0.0138	0.8431	0.5533	0.0024	0.0038	0.0001	0.2381
TFEM [2]	0.4824	0.5691	0.4254	0.0692	0.0977	0.2222	0.0533
TFDE [3]	0.2930	0.8436	0.2249	0.6860	0.3682	0.9638	0.4568
Egg weight (g)	0.3689	0.4677	0.2554	0.0037	0.1413	0.0079	0.0158
Specific gravity	0.0287	0.9548	0.8844	0.2326	0.9420	0.1227	0.6033
% breast of BW	0.7410	0.3748	0.9879	0.2306	0.3933	0.6165	0.1154
% fat pad of BW	0.0367	0.6014	0.2077	0.3944	0.5088	0.0435	0.5816

[1] Total Hen Day Production, [2] Total Feed Egg Mass, [3] Total Feed Dozen Egg

Table 9: Daily lysine intake (grams/hen)

	Treatments								
	1	2	3	4	5	6	7	8	9
9 weeks	0.731	0.810	0.834	0.838	0.793	0.805	0.740	0.799	0.832
1 weeks	0.756	0.814	0.851	0.846	0.812	0.858	0.756	0.814	0.835
3 weeks	0.765	0.826	0.886	0.758	0.750	0.836	0.769	0.838	0.873
5 weeks	0.746	0.821	0.879	0.633	0.649	0.738	0.757	0.805	0.831

Table 10: Manure composition (all data based on dry matter) from 19 to 65 weeks of age.

	Treatments									Strain		SEM	X
	1	2	3	4	5	6	7	8	9	Babcock	Shaver		
Ammonium-N (kg/t)	2529.4	3041.9	2705.0	2694.2	2679.2	2882.5	2635.0	2851.9	2983.1	2712.7	2843.3	131.9	NS
Calcium (%)	5.105	3.500	4.757	5.085	3.891	3.566	5.156	5.179	4.191	4.622	4.362	0.205	NS
K2O (%)	1.244	1.467	1.499	1.404	1.380	1.590	1.356	1.547	1.612	1.451	1.459	0.055	NS
Magnesium (%)	0.521	0.532	0.508	0.548	0.551	0.541	0.536	0.526	0.527	0.539	0.526	0.018	NS
P2O5 (%)	3.806	4.144	3.553	3.725	3.797	3.150	3.722	3.734	3.834	3.667	3.770	0.145	NS
Phos. (%)	1.661	1.808	1.551	1.626	1.657	1.375	1.624	1.629	1.673	1.600	1.645	0.063	NS
Potassium (%)	1.032	1.218	1.244	1.166	1.147	1.318	1.125	1.283	1.338	1.205	1.211	0.045	NS
Sodium (%)	0.099	0.116	0.115	0.105	0.108	0.091	0.097	0.160	0.112	0.115	0.108	0.007	NS
Org Nitrogen (%)	6.971^{b}	7.471^{ab}	7.384^{ab}	6.944^{b}	7.210^{b}	7.858^{a}	7.059^{b}	7.080^{b}	7.436^{ab}	7.263	7.273	0.066	0.0118
Tot. Nitrogen (%)	7.224^{c}	7.776^{ab}	7.655^{abc}	7.215^{c}	7.478^{bc}	8.148^{a}	7.323^{bc}	7.364^{bc}	7.734^{abc}	7.535	7.558	0.061	0.0013
Tot. Sulphur (%)	0.428^{c}	0.464^{abc}	0.449^{bc}	0.433^{bc}	0.471^{ab}	0.503^{a}	0.444^{bc}	0.466^{abc}	0.471^{ab}	0.459	0.458	0.005	0.0214
Uric acid (%)	14.37^{b}	15.43^{a}	14.71^{ab}	14.23^{b}	14.40^{b}	15.55^{a}	14.01^{b}	14.58^{ab}	14.72^{ab}	14.55	14.78	0.103	NS
Uric acid/ Tot. Nitrogen	1.995	1.989	1.931	1.979	1.929	1.918	1.926	1.993	1.909	1.941	1.964	0.039	NS
Ratio N used (%)	39.046	37.263	34.439	41.144	39.382	35.918	36.040	34.251	44.313	37.425	38.529	1.231	NS
Volume manure (g/h/d)	24.74	26.36	29.12	25.43	25.99	25.46	25.99	28.33	23.96	26.42	25.90	0.515	NS

$^{a-b-c}$ Means within a row with no common superscript differ significantly ($P<0.05$)

Table 11 Apriori contrasts P values for manure composition from 19 to 65 weeks of age.

	Contrasts						
	1 vs 7	2 vs 8	3 vs 9	3 vs 4 & 6	2 vs 5	3 vs 4	3 vs 6
Ammonium-N (kg/t)	0.8583	0.7480	0.6383	0.8707	0.5400	0.9854	0.7641
Calcium (%)	0.8825	0.1193	0.7464	0.6169	0.5763	0.8046	0.2663
K2O (%)	0.7307	0.7735	0.7482	0.9767	0.7863	0.7911	0.7525
Magnesium (%)	0.9015	0.9536	0.8439	0.6352	0.8486	0.6439	0.7192
P2O5 (%)	0.8001	0.7017	0.7182	0.9479	0.7268	0.7093	0.6271
Phos. (%)	0.8188	0.6645	0.7170	0.9114	0.7039	0.7375	0.5977
Potassium (%)	0.7222	0.7791	0.7360	0.9791	0.7831	0.7869	0.7522
Sodium (%)	0.9424	0.1550	0.9096	0.5105	0.7403	0.7316	0.4256
Org Nitrogen (%)	0.7875	0.1152	0.8634	0.9927	0.3249	0.0929	0.0899
Tot. Nitrogen (%)	0.7242	0.0609	0.7510	0.9627	0.2014	0.0541	0.0450
Tot. Sulphur (%)	0.4183	0.9279	0.2379	0.2670	0.7014	0.3634	0.0052
Uric acid (%)	0.347	0.062	0.976	0.725	0.022	0.259	0.083

Administrative and Other Aspects

Data from this research was presented at the Poultry Science Annual Meeting in St-Louis MO.

Audren, G.P., H.L. Classen, K. Schwean-Lardner and K. Bolton. 2004 Amino acid requirements of laying hens. Poultry Science, *83, Suppl 1:430*

An extension meeting took place on January 5, 2005 to present the results of the experiment and make recommendations to the Saskatchewan egg producers.

A workshop for the Saskatchewan Egg Producers on manure management is scheduled for spring 2005. This workshop will be organized in collaboration with Karen Bolton from Saskatchewan Agriculture, Food and Rural Revitalization.